Ground-based Testing of TiB_2 and Al_2O_3/TiB_2 Response to Space Environment

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Outline

- Background
- Test materials
- Experiments and discussion
  - Atomic oxygen (AO) exposure
  - Neutron shielding
- Conclusions
- Questions

General Background

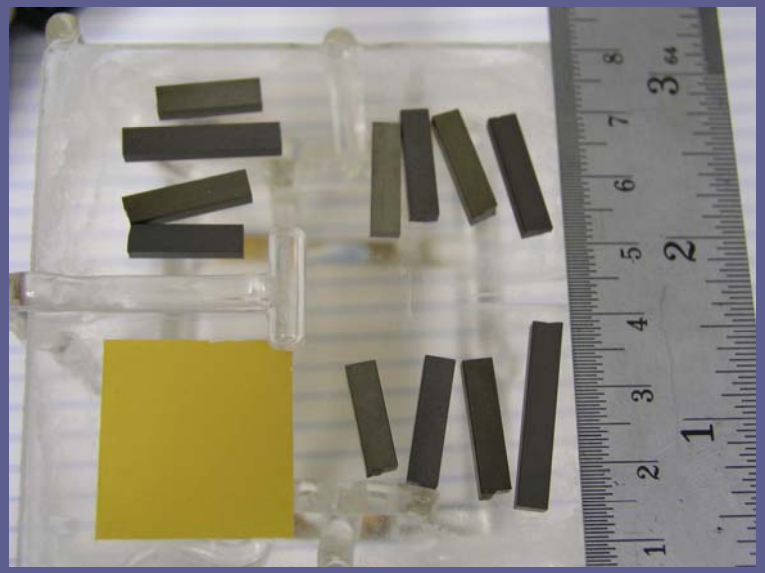
- Constant search for improved space materials
- Low Earth Orbit
  - Highly reactive AO environment
  - Galactic cosmic ray induced neutron radiation
- Unique TiB_2 material
  - Carbonless SHS production
  - Improved performance
- Boron has high neutron capture cross-section
- Selection for MISSE 6
  - Minimal prior space environment testing

Test Materials

TiB_2 Characteristics	
Density	4.53 g/cm^3
Melting Point	3000° C
Fracture Toughness	5 - 6 $MPa * m^{1/2}$
Hardness	3400 Knoop
Electrical Conductivity	9 - 18 $\mu\Omega * cm$
Chemical Stability	Resistant to acids
High Thermal Conductivity	
Excellent Thermal Shock Resistance	

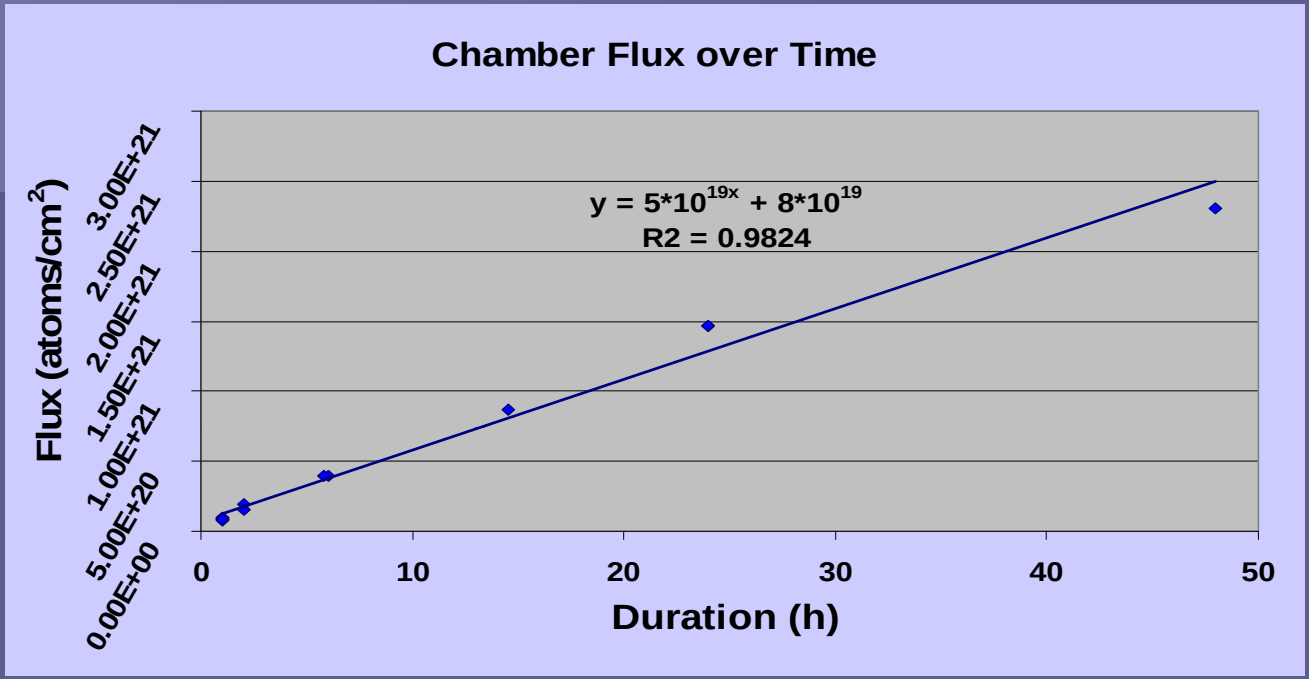
Atomic Oxygen Exposure Test

- Purpose: Determine effects of AO exposure
- Exposures of varying durations
- Ground state AO
- No significant oxidation or erosion expected



Placement of samples on glass holder

AO Exposure Test Procedure



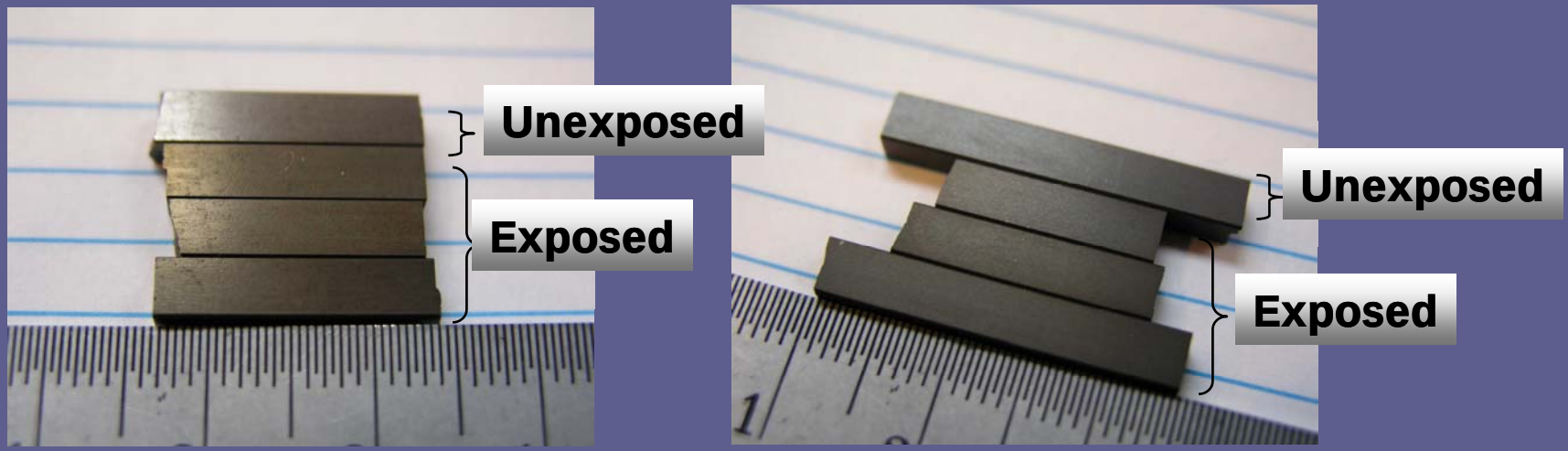
Fluence = $\Delta m_K / (A_K r_K E_K)$ atoms/cm^2

Δm_K = mass loss of Kapton sample, E_K = Kapton sample erosion rate ($3.0*10^{-24}$ cm^3/atom), A_K = Kapton sample area (6.45 cm^2), r_K = Kapton sample density (1.42 g/cm^3)

- Average AO fluence: 6.72 x 10^{19} atom/cm^2/hr
- Longest equivalent test duration: 10.6 months

AO Exposure Test Results

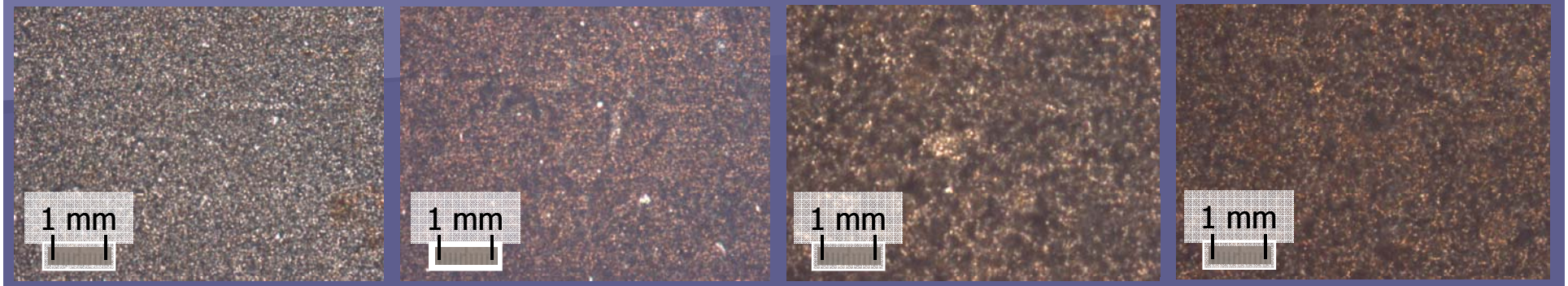
- No significant oxidation or erosion detected
- Slight yellowing
  - Coincides with previous study
  - Indicative of slight oxidation



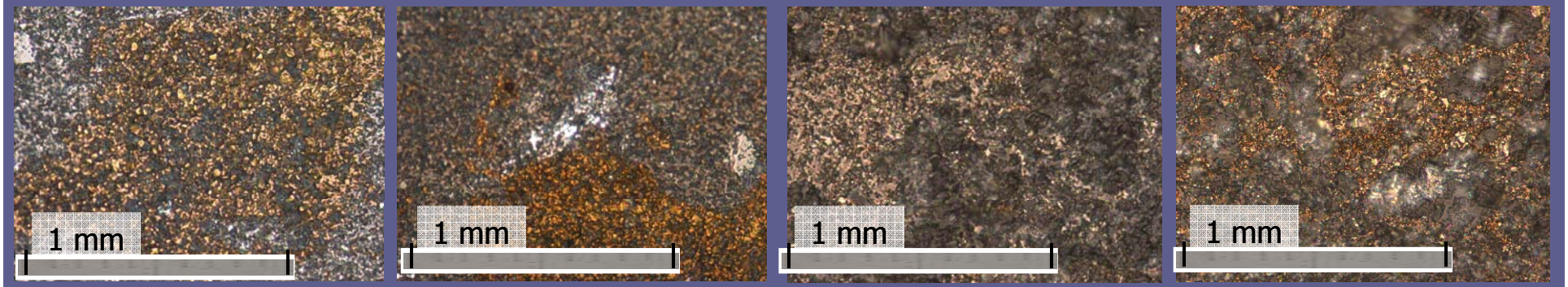
Comparison of unexposed and exposed samples Left: TiB_2 (14.5 hr exp), Right: Al_2O_3/TiB_2 (14.5 hr exp)

AO Exposure Test Results – Optical

10X

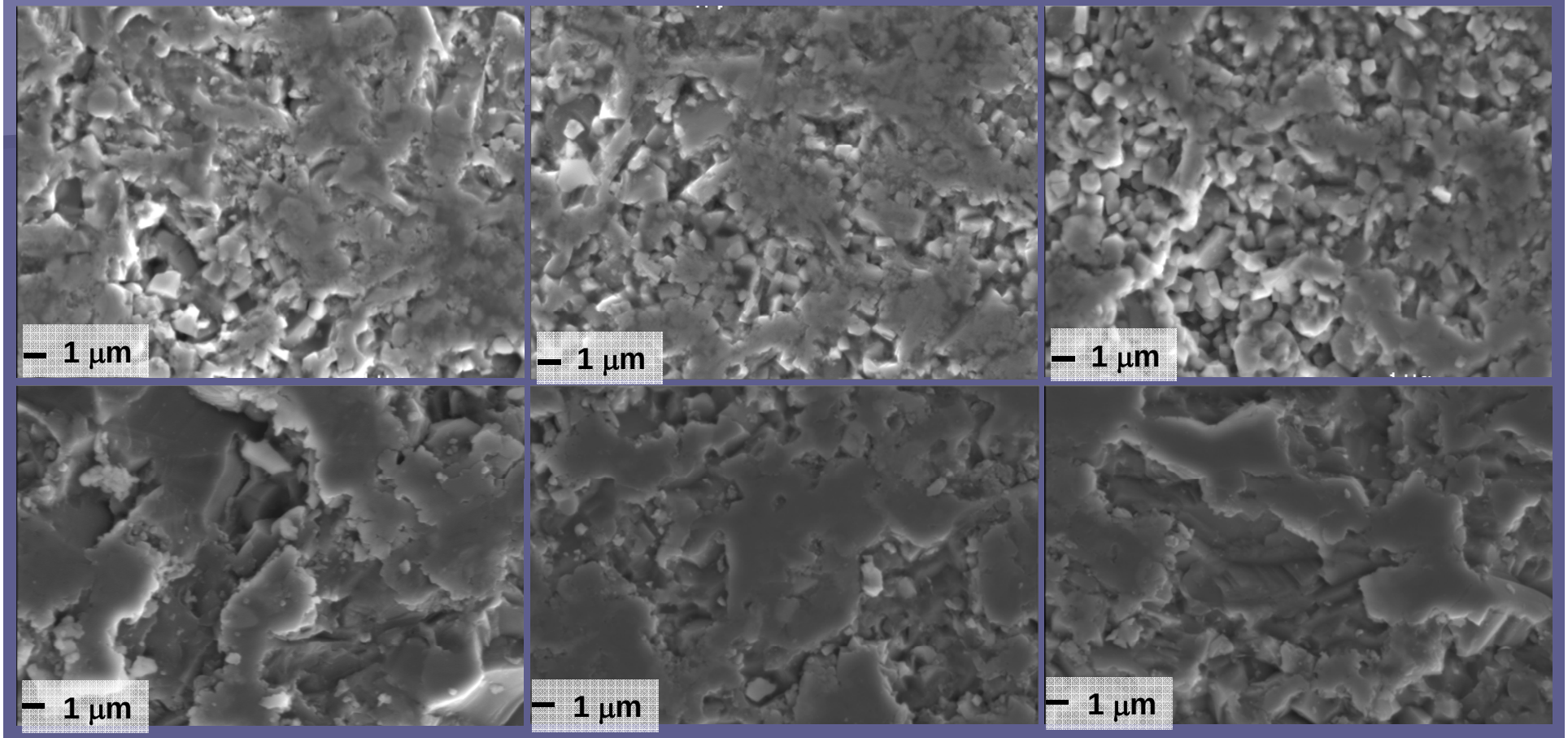


50X



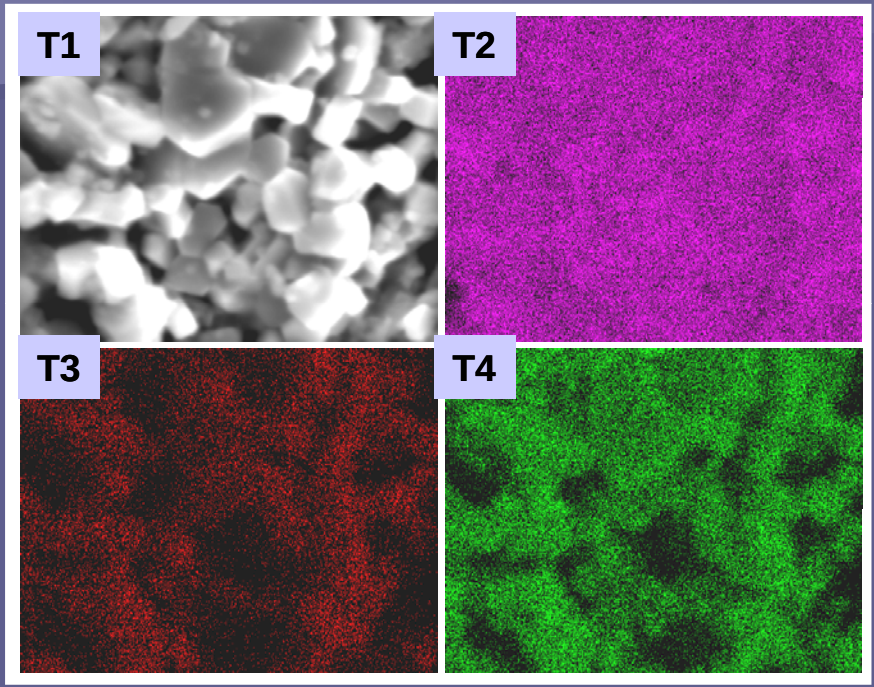
Optical magnification pictures (top: 10X, Bottom: 50X)
Left to right: Unexposed TiB_2. 24 hr exposed TiB_2, Unexposed Al_2O_3/TiB_2. 24 hr exposed Al_2O_3/TiB_2

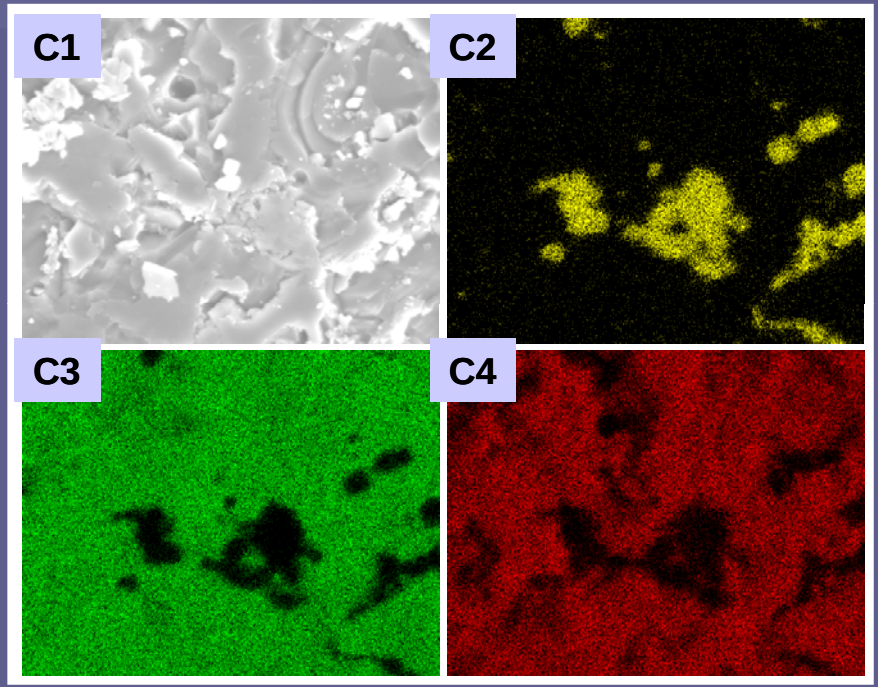
AO Exposure Test Results – SEM



5000X magnification SEM (Top: TiB_2; Bottom: Al_2O_3/TiB_2)
Left: unexposed; Center: 6 hr exposure; Right: 24 hr exposure

AO Exposure Test Results – EDAX





EDAX mappings of samples after 24 hours exposure
Left: TiB_2 (T1), Ti (T2), B (T3), O (T4)
Right: TiB_2/Al_2O_3 (C1), Ti (C2), Al (C3), O (C4)

AO Exposure Test Results

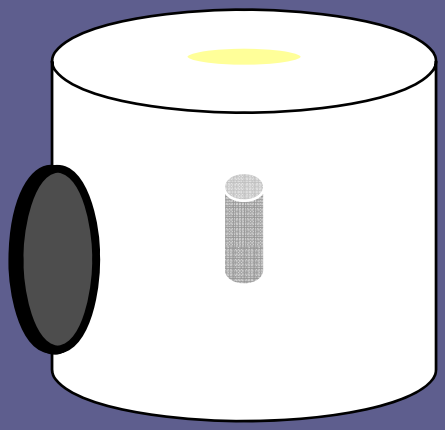
- No significant mass changes with either material
- XPS, EDAX showed oxides present in control and exposed samples
- EDAX found presence of contamination (silica) on surface of material samples
  - Sample holder etching suspected as source
  - Negligible impact on mass readings

Neutron Shielding Test

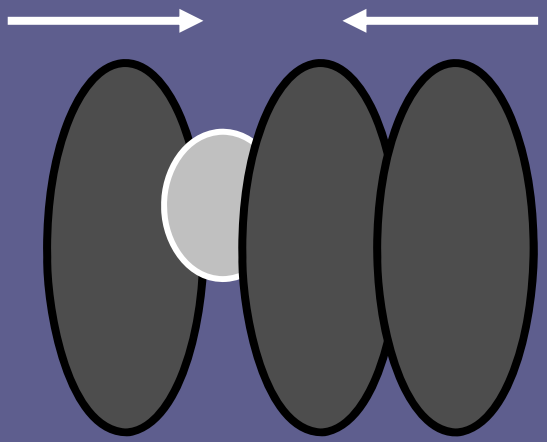
- Purpose: Determine TiB_2 and Al_2O_3/TiB_2 neutron shielding ability
- Exposure to moderated neutron source
  - Source: 1 Ci Am 241/Be 9
  - Moderation: 2 inch-walled polyethylene cylinder
  - Average neutron energy: ≤ 1MeV
- Expectations:
  - Reduced radiation transmission
  - TiB_2 performs better than Al_2O_3/TiB_2

Neutron Shielding Test Procedure

- Indium foil detector
  - 54.4 minute half life
  - Reaction path: $^{115}In + n \rightarrow {}^{116}Sn + \beta^-$
- Sample placed touching source container
- Minimum 24 hour exposure



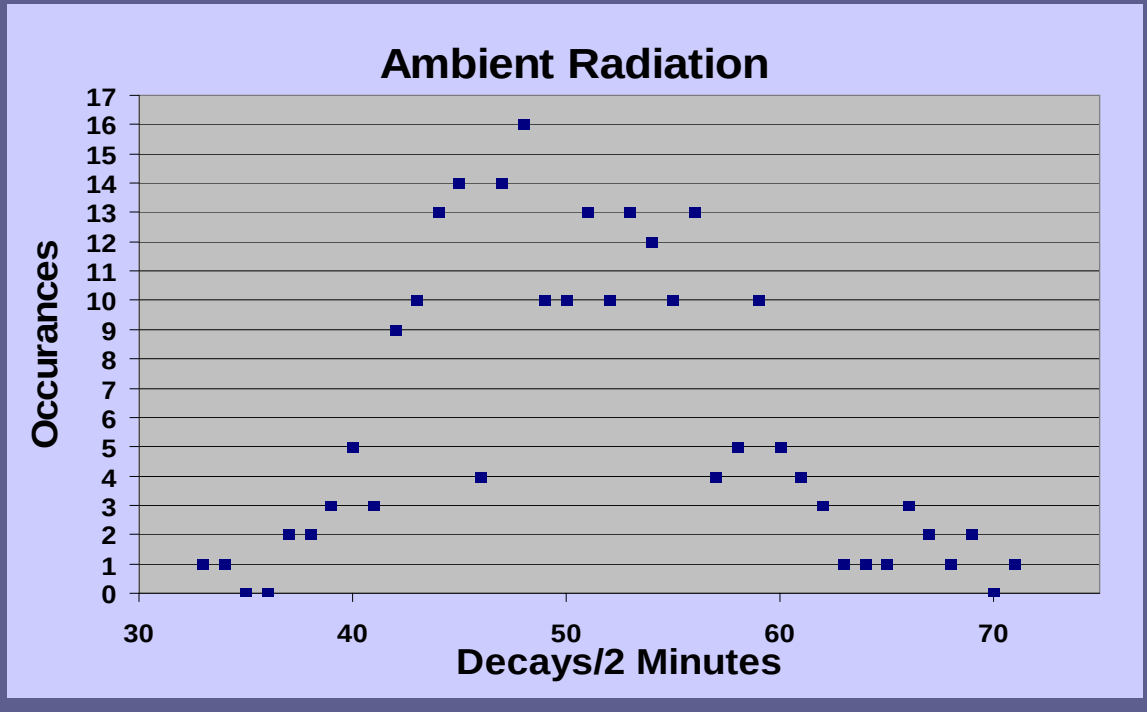
Sample placement with source



Sample set (left to right):
1mm composite back layer, In foil, 1mm test material layers

Neutron Shielding Test Procedure

- Radiation detection
  - Model 500 Nuclear Scaler radiation counter
  - Ambient radiation readings
  - Indium detector radiation reading
    - 2-minute counts, 5-minute intervals, 2 hour period
  - Ambient correction applied



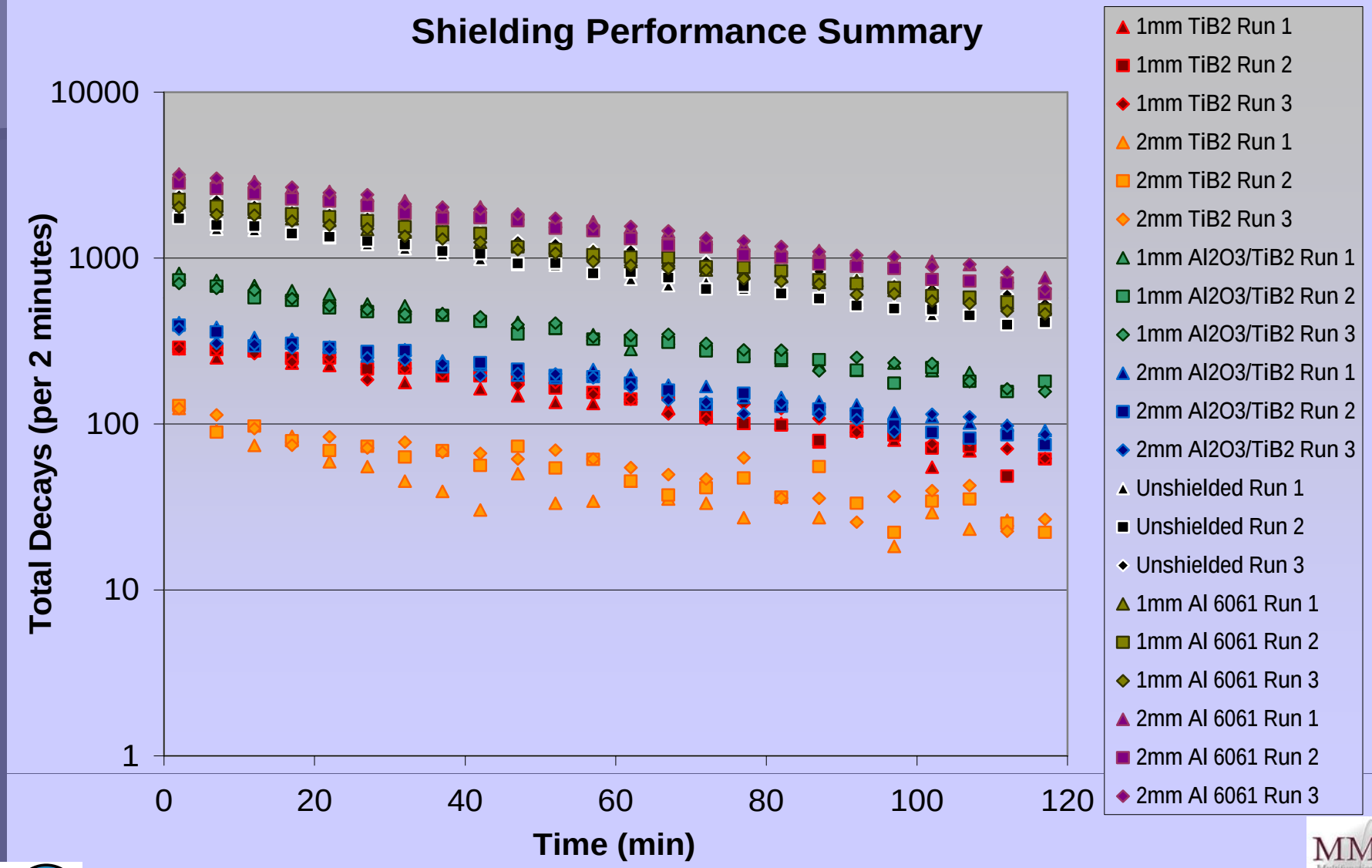
Neutron Shielding Results

- TiB_2 exhibits significant shielding ability
- Al_2O_3/TiB_2 exhibits shielding enhancement
- Al 6061 produces radiation increase

Radiation reductions							
	None	1mm TiB2	2mm TiB2	1mm Comp	2mm Comp	1mm Al 6061	2mm Al 6061
Run 1	1744	306	105	782	395	2179	3315
Run 2	1779	336	77	690	399	2309	2906
Run 3	2450	313	112	717	352	2077	3305
Average	1991	318	98	730	382	2188	3175
		84.03%	**95.08%**	**63.34%**	**80.81%**	**-9.89%**	**-59.47%**

Radiation shielding percentages by material and thickness

Neutron Results



Conclusions

- Atomic oxygen
  - No significant surface changes
  - Potential oxidation observed
- Neutron shielding
  - 1 mm TiB_2 provides ~ 84% reduction in neutron transmission
  - 1 mm Al_2O_3/TiB_2 provides ~ 63% reduction
  - Al_2O_3/TiB_2 requires over 2X TiB_2 thickness to match effectiveness

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Questions?

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